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OF

TOBACCO CURED BY THE LEAF-CURE ON WIRE AND THE STALK PROCESSES.

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RESULTS OF CHEMICAL ANALYSES

OF

TOBACCO CURED BY THE LEAF-CURE ON WIRE AND THE STALK PROCESSES.

By F. B. CARPENTER, Assistant Chemist.

INTRODUCTION.

This bulletin is supplementary to one already published by this Station (Bulletin No. 86), entitled "Tobacco Curing by the Leaf Cure on Wire, and the Stalk Processes." It was stated in that bulletin that the object of the experiment was "to test the comparative merits of the two systems of curing tobacco for market, especially of the variety known as yellow tobacco, grown particularly in the States of North Carolina and Virginia—namely, the old-style stalk-cure, and the newer method of curing the leaves alone, pulled from the stalk as they become ripe. Though not strictly new, public attention was specially drawn to the latter plan through the efforts of Capt. W. H. Snow, of High Point, N. C., in connection with an improved curing barn advocated by him. The main point of distinction between the two systems of curing is, that in the stalk-cure, when the leaves are ripe on the stalk, the whole stalk is cut down, and, with the accompanying leaves, is cured on a stick in the old-style log-barn. In the leaf-cure system, the leaves, as they mature on the stalk, are cut off (commencing at the bottom), stuck on wires, and cured, while the stalk is still standing in the field. The cure is made either in an old-style log-barn, or, better, in a patented barn of improved construction, known as the Snow barn, which possesses principles that must commend themselves for their simplicity and scientific thoroughness."

Bulletin No. 86 dealt with the merits of the two systems with reference to the comparative values as influenced by quantity, quality, expense of management, etc., while this bulletin discusses the chemical compositions of the tobacco as cured by the two methods.

In dealing with tobacco from a chemical standpoint, we have first to consider the conditions which surround the plant during its various stages of growth, and then the changes which take place in the various processes of curing, fermentation, and manufacture. Of all the conditions which influence the quality of tobacco, there is probably none which makes more marked variations than that of climate. The plant has a widespread cultivation, extending through

a wide range of territory, including portions of the tropical and temperate zones. The fine aromatic flavor, upon which the value largely depends, seems to be most properly developed in the plant by the agencies of high temperature and moisture.

Little can be done, however, to change the influences of climate, but the other conditions that must be fulfilled in order to succeed in the cultivation of the crop may be modified to produce the desired result.

The quality also depends, to a large extent, on the character of the soil. While the plant thrives best in a soil rich in fertilizing ingredients, too much organic matter tends to make the leaves coarse and heavy at the expense of quality. The finest leaves are produced on a light sand, or sandy loam, having an average amount of organic matter. The soil seldom possesses the elements of plant food in such a form as to be conducive to the production of a fine tobacco leaf. This deficiency must be supplied by the application of suitable fertilizers. Care must be exercised in the selection of the proper elements of plant food, for ingredients might be taken up by the plant which would be detrimental to its burning qualities, or other properties which give to it its value.

The various properties of the leaf are thus more or less affected by the climate, soil, fertilizers, mode of cultivation, time of harvesting, etc.

While, therefore, it is permissible to trace out the relations between Nature and the proportions of the various constituents, we must also consider the treatment to which the plant is subjected after it has been removed from Nature's laboratory, and note what effect this subsequent treatment has on the finished product. There are various processes of curing, fermenting and flavoring which affect, in one way or another, the quality and composition of the commercial article. The experiment already made only includes two of the many different processes, namely, curing by the leaf process and the stalk process.

The Constituents of Tobacco.

The constituents of tobacco are present in varied proportions in different tobaccos, and the variation is still more noticeable in the commercial article which has been subjected to the different processes of curing and manufacture. The results of chemical analysis show that the same constituents, with a few exceptions, are found to be present, to a greater or less extent, in all varieties. The constituents already identified in the leaf of the tobacco plant are as follows:

Nicotine ($C_{10}H_{14}N_2$).—This alkaloid is the active principle of tobacco. It consists of a volatile oily substance, and possesses a strong tobacco odor. It has been ascertained that nicotine is present in the largest quantities in the ripe leaf, while the percentage decreases in the young and overripe leaves. Though the narcotic effects must

be partly due to this alkaloid, it cannot be said that they are wholly due to it. Some tobaccos contain little or no nicotine, yet smokers consider cigars made from this tobacco to be strong.

Nicotianine ($C_{23}H_{32}N_2O_3$).—A volatile substance of the consistency and appearance of camphor, possessing the odor of tobacco, and an acrid, aromatic, and bitter taste. It forms no compounds with acids or alkalies, and is supposed to be the substance to which the characteristic odor and flavor of tobacco are chiefly due.

Resinous and Fatty Substances.—Under this head we include the resin, wax, oil, and fat, the nature of which, as yet, little is known. These substances are present in considerable proportions in tobacco, and it is probable that the odor of the smoke is greatly influenced by them.

Starch ($(C_6H_{10}O_5)_n$).—Starch exists in tobacco, as in most plants, but in smaller proportions.

Glucose ($C_6H_{12}O_6$).—This sugar is present in small proportions in the green plant, but it is generally stated that cured tobacco contains no sugar. While this is true in many cases, there are varieties which have a large percentage of sugar, which, when cured by certain processes, nearly the entire amount remains unchanged in the leaf. Such is the case with the tobacco analyzed and reported in this bulletin. The carefully regulated drying by artificial heat has reduced the fermentation to a minimum, and left the glucose unchanged.

Nitrogenous Substances.—Nitrogen is present in small quantities in nicotine, nicotianine, ammonia, and nitric acid, but there are much larger proportions in nitrogenous organic substances. These latter are to be regarded as products altered from the original albuminous substances present in the green leaf.

Pectic acid ($C_{16}H_{22}O_{15}$) is supposed to exist in tobacco as calcium pectate. It is found in the largest proportions in the stem, and smallest in the stalk. This insoluble lime-salt, together with cellulose, gives stiffness to the leaf.

Acetic acid ($C_2H_4O_2$) is present in nearly all tobaccos in small proportions, and is probably, for the most part, the product of fermentative changes.

Malic acid ($C_4H_6O_5$) forms from six to ten per cent. of the cured leaf, while in the stalk the amount is very small.

Citric ($C_6H_8O_7$) and *Oxalic acid* ($C_2H_2O_4$) are always present in tobacco in varying but usually small proportions.

Nitric acid (HNO_3) is sometimes present to the extent of three to four per cent. of the cured leaf, while in other cases there is not a trace to be found. Nessler attributed the presence of this substance to the decomposition of other nitrogenous substances by fermentation. It is more probable, however, that the nitric acid was taken in through the roots in the process of nutrition, as will be shown in this bulletin under the head of "Nitrates in Tobacco."

Ammonia (NH_3) is always present in the cured tobacco in small proportions. It is supposed to be the product of fermentation.

Cellulose ($C_6H_{10}O_5)_n$ forms from six to fifteen per cent. of the leaf, while the stalk contains from thirty to forty per cent. This material constitutes the frame-work of the plant, and bears an important relation to the character of the leaf. According to Nessler, the quality of tobacco for smoking increases to a certain extent as the cellulose increases, and that of the extractive substances diminish.

Organic Substances.—Substances other than those previously enumerated are present in tobacco, the nature of which has not been fully investigated. The character of some of these substances, which exist in the green plant, is entirely changed in the fermented product.

Mineral Ingredients—The proportion of mineral ingredients in the leaf varies in different tobaccos from 8 to 27 per cent., while that of the stalk is very much less. The quality of the leaf is greatly influenced by the amount and nature of the mineral constituents. These constituents consist of combinations of potash, soda, lime, magnesia, phosphoric acid, iron, alumina, silica, chlorine, sulphuric acid, and sometimes a trace of manganese. These substances are present in varying proportions in different varieties, but there are usually large percentages of potash and lime present. It is generally supposed that the presence of a large percentage of potash is beneficial for smoking purposes, while chlorine is generally considered deleterious.

METHODS OF ANALYSIS.

Tobacco analysis has received but little attention in this country, hence we have adopted no official methods of analysis. Many of the methods now in use are old, and while some are good others are quite inaccurate. It has been the purpose in selecting the methods used in this bulletin to choose those which would be of practical application, combined with simplicity and accuracy.

The basis of the following scheme of analysis is compiled from the methods of Grandeau, Schloessing, Fresenius, Nessler, Patterson, Kessling, Association of Official Agricultural Chemists, and the Sixth Annual Report of the New York Station, to which modifications and additions have been made.

Organic Analysis.

Preparation of Samples.—The cured leaves are stemmed, and then allowed to thoroughly dry at the temperature of the grinding-room. The two portions are then weighed, ground so as to pass through a 1-36 inch sieve, and preserved in air-tight jars. The grinding will have to be done on a very dry day, or the tobacco will become too wet to handle. The different determinations are to be made from these finely-ground air dry samples, and the results afterwards calculated to water-free basis.

Moisture.—Two to three grams are dried for four hours, heating fully to the temperature of boiling water.

Nicotine.—Take 5 to 10 grams tobacco, and thoroughly saturate it with an alcoholic solution of soda (6 grams $NaOH$ in 40 c. c. H_2O and 60 c. c. 95 per cent. alcohol.) Allow this to stand for several hours to partially dry out and drive off the ammonia. Then transfer to an extractor and extract with ether for 8 hours, collecting the extract in a 300 c. c. flask The extract is then made slightly acid with sulphuric acid, and the ether evaporated off, using a very gentle heat. To this residue add 150 to 200 c. c. diluted soda hydrate solution (4 : 100), and distill off the nicotine. Titrate the distillate with $\frac{n}{10}$ sulphuric acid, cochineal being used as an indicator. Forty-nine (49) parts by weight of H_2SO_4 being equal to 162 parts by weight of nicotine.

Nitric acid (Qualitative).—The qualitative test is made as follows: Two or three grams of the substance are placed in a beaker, thoroughly mixed with a small amount of water, and allowed to stand for a short time. This is then filtered off, and a few drops are placed on a porcelain crucible cover; a few drops of concentrated sulphuric acid, in which some brucine has been dissolved, is now brought on the cover, and the two solutions are allowed to mix. If

a bright-red color is formed where the two solutions meet, then nitric acid is present. This is a very delicate test, and, if properly handled, is very satisfactory.

Nitric acid (Quantitative).—Use the Tiemann-Schultze method as described by Fresenius (Quantitative Chemical Analysis, p. 473). It is, however, more convenient to use a nitrometer according to Schiff, or some other convenient form, and the tobacco may be weighed and transferred directly to the flask, the amount taken to be varied according to the amount of nitric acid present.

Total Nitrogen.—Determine by the Kjeldahl method of the Association of Official Agricultural Chemists (Bulletin 31, Division of Chemistry, U. S. Department of Agriculture, p. 184).

Ammonia.—Weigh out 10 grams of tobacco, and transfer to a Kjeldahl distillation flask. To this add 200 c. c ammonia-free water and 1 to 2 grams of recently ignited magnesia; distill this solution until the distillate is no longer alkaline, catching the distillate in very dilute sulphuric acid. Precipitate the nicotine in this solution with mercurio-potassic iodide. Filter, and wash thoroughly with water. Add sufficient potassium sulphide to the filtrate and washings to precipitate the excess of mercury; then make alkaline with sodium hydrate, and distill off the ammonia, catching it in $\frac{n}{10}$ sulphuric acid. Determine the ammonia by titration.

Albuminoids.—The nitrogenous substances termed albuminoids are found by multiplying by 6.25 the residue left on deducting from the total nitrogen, the nitrogen contained in the nicotine, ammonia and nitric acid.

Ether Extract.—Place 2 grams of water-free tobacco in an extractor and extract for 24 hours with anhydrous ether. Evaporate off the ether, dry and weigh. This long continued extraction with ether is found to take out nearly all of what would be termed resinous or fatty substances. An additional extraction with absolute alcohol will remove what has not been removed by the ether. This residue must, however, be washed with water, as the alcohol removes other substances besides the resins. A few experiments made by extracting with both ether and alcohol, washing the residues with water, drying, and weighing, gave nearly the same results as the ether extract alone without washing the residue. The extraction with alcohol being somewhat difficult to manage, it was thought preferable, for the comparison in this bulletin, to extract with ether alone.

Cellulose.—Proceed according to method for crude fiber, Bulletin 31, U. S. Dept. Agr., Div. of Chem., p. 190.

Pectic Acid.—Weigh out 2 grams tobacco and transfer to a filter, wash slowly with 80 per cent. alcohol, with which one-fourth the quantity of concentrated hydrochloric acid has been mixed. When the filtrate contains no further trace of lime, the acid is completely washed out with 80 per cent. alcohol. By this method the pectic

acid is separated without any loss. The substance is now transferred to a 500 c. c. Erlenmeyer flask, which is filled to three-fourths of its capacity with distilled water. To this solution add at least 2 grams of oxalate of ammonia to each gram of pectic acid, and heat in a water-bath at 35° C. for three to four hours. Oxalate of ammonia, like other salts of organic acids, has the property of dissolving pectic acid. Furthermore, this solution is much easier to filter than an alkaline pectic acid solution. After filtering and washing, precipitate the filtrate with acetate of lime in excess. The precipitate consists of oxalate and pectate of lime, from which the pectic acid can be separated by washing slowly with alcohol strongly acidified with hydrochloric acid. This operation may be avoided if one has weighed the amount of oxalate of ammonia used. In this case filter the oxalate and pectate of lime on tared filters; wash with water, then with alcohol; dry at 100° C. and weigh. Now calcine the precipitate obtained, deduct the amount of lime which was combined with the oxalate of ammonia employed, and the residue is the lime combined with the pectic acid. The oxalate and pectate of lime, minus the oxalate of lime, gives the pectate of lime and this, minus the lime combined with it, gives the pectic acid.

Glucose.—Five to ten grams of the substance are placed in a beaker, with a small amount of water, and allowed to stand for 1 or 2 hours. Filter, and wash until all the glucose is removed. This is generally accomplished when the filtrate and washings amount to 200 c. c. Treat this solution with a slight excess of basic acetate of lead; filter, and wash thoroughly. Remove the excess of lead with sodium carbonate, and determine the glucose in an aliquot part of this solution with Fehling's solution.

Starch.—The residue from the preceding determination is placed in a flask of 250 c. c. capacity, 150 c. c. of distilled water, 4 to 5 c. c. of concentrated hydrochloric acid added, and the flask closed by a cork having a small glass tube, about three feet long, inserted in it to act as a condenser. The flask is then put in a water-bath, and kept at the temperature of boiling water for twelve hours. The flask is allowed to stand over night; the solution is then filtered off, the filtrate neutralized with sodium carbonate, and the washing continued until all the glucose is washed out, which is generally accomplished when the filtrate and washings amount to 200 c. c. The gluclose is then determined by Fehling's solution, as in the preceding case, and the starch calculated from the result.

Acetic Acid.—The solubility of acetic acid salts in water and alcohol precludes the use of the precipitation method of estimating this acid. But acetic acid is volatile, and this peculiarity may be advantageously employed to furnish a very simple method for separating it. Use a stream of steam to volatilize the acetic acid, which has been previously freed from its bases by a stronger non-volatile acid. A convenient apparatus for this determination consists of a glass

cylinder 2 to 2½ inches in diameter and 15 inches long, having the ends contracted so as to receive rubber stoppers. This is clamped in a retort stand at an angle of about 45°; the lower end is connected with a glass tube, which dips in a jar of water. In the upper end is inserted a rubber stopper with two holes. One hole is connected by a glass tube with a distillation flask. A glass tube passes through the other hole, which is connected with a Kjeldahl condenser on the outer end, while the inner is attached by means of a rubber stopper, with a glass cylinder about 6 inches long and 1½ inches in diameter, having the ends slightly contracted. Three to five grams of finely pulverized tobacco are wet with a few c. c. water, to which a little finely pulverized tartaric acid has been mixed. This is placed in the inner cylinder between two layers of loose cotton wool, or, better, glass wool. The distillation flask is now partly filled with water and boiled until the distillate is no longer acid. Twenty to thirty minutes is usually long enough to separate all the acid. The steam passes from the flask into the outer cylinder, then through the material in the small cylinder to the condenser, carrying the acetic acid with it. It is here condensed and collected in distilled water, allowing the lower end of the condenser to dip in the water. The distillation having been completed, the acetic acid is determined with $\frac{n}{10}$ standard alkali, using phenolthaline as an indicator. The outer cylinder plays a very important part in this determination, as it keeps the inner tube the same temperature on the outside as inside, thus preventing the steam from condensing while passing through the tobacco. The steam which is condensed in the outer tube is collected in the jar of water at the lower end.

Oxalic, Citric, and Malic Acids.—The solution of these acids and their salts in tobacco could be obtained with acidified water or alcohol, but both these mediums dissolve, also, other substances from which the separation of the acids is very difficult. It is, therefore, desirable that the exhaustion be conducted with ether, which, in general, dissolves neither mineral salts nor albuminous substances. The employment of ether requires that the organic acids be liberated by the use of some stronger acid, as, for example, sulphuric acid. Examine first the ash of the substance, so that the minimum amount of sulphuric acid can be calculated, which the bases, not combined with mineral acid, require. The ash of tobacco, for instance, may contain 60 per cent. carbonate of lime, 10 per cent. carbonate of potash and 5 per cent. carbonate of magnesia. This would require 64 per cent. SO_3. If, therefore, we have 10 grams of substance for the extraction, the ash will weigh 2 grams, and will require a minimum of 1.3 gr. SO_3. To insure the freeing of the organic acids it is customary to use double the minimum amount, or, in this case, 2.6 gr. of SO_3. Care must be observed not to use more than this proportion, as it might be carried over with the ether, and would cause trouble in the different determinations. After the sulphuric acid is diluted with four to five times its

weight of water, the proper amount is poured on 5 to 10 grams of tobacco, and thoroughly mixed in a mortar; work the mass lightly to remove the sap, then mix with a small quantity of pumice stone; transfer the whole to a Soxhlet extractor, and subject it to a continuous extraction with ether for at least 15 hours. The operation is considered complete when a few drops, caught from the outlet of the extractor, evaporate readily, showing that there is no acid to hinder the evaporation. The ether removes neither the nitric, hydrochloric, or sulphuric acids, but completely all traces of phosphoric acid. Evaporate the ether until there is but a few c. c. left in the flask, then add a few c. c. of water, and mix very slowly with the etherial fluid to insure the complete solution of the acids. Finally transfer to a beaker, and wash thoroughly. Unite the wash-water with the solution in the beaker, and evaporate the ether at the lowest possible temperature. The solution is now ready for the determination of the organic acids.

Oxalic Acid.—Neutralize with ammonia, make slightly acid with acetic acid, and precipitate the oxalic acid with a dilute solution of acetate of lime, avoiding an excess, since it would interfere with the other determinations. After the oxalic acid is completely separated filter, wash thoroughly, ignite, and weigh. The percentage of oxalic acid is calculated from the lime thus obtained.

Citric Acid.—The filtrate from the preceding determination is made very slightly acid with acetic acid. Now add slowly, with constant stirring, a dilute solution of acetate of lead until a permanent precipitate appears. When the supernatant liquid is clear draw off a few c. c. by means of a pipette, and transfer to a small beaker. To this solution add a few drops of acetic acid and a small amount of a very dilute solution of acetate of lead, and observe from this portion of the liquid whether a permanent precipitate can be obtained, or whether it dissolves again in the acetic acid. In the first case we must continue to add acetate of lead to the original solution and again test a small portion, and so continue until we get a sample in which the precipitate redissolves in acetic acid. At this moment the citric acid is completely precipitated. The samples taken out to test must be neutralized with ammonia, and washed back into the original solution. Let stand for a few hours filter on a tared filter, wash first with water to which a few drops of acetate of lead and acetic acid have been added, then with 80 per cent. alcohol, and conclude the washing with a mixture of equal parts of water and alcohol. Dry the precipitate, weigh, ignite at a low heat in porcelain crucible, and weigh again. The loss in weight is counted as citric acid. In the filtrate, under the influence of the alcohol, the small portion of citrates still in solution separates and falls with the malates. These are filtered out, washed with alcohol, dried, ignited, weighed, and calculated as half citrate and half malate of lead. The conjoint weight of both acids is so small that the error that might arise from this source is very small.

Malic acid.—The alcohol is evaporated off from the last filtrate. When this has been completed the liquid is agitated with acetic acid in excess, and a sufficient amount of acetate of lead having been added, the whole is overflowed with 5 to 6 volumes of 80 per cent. alcohol, containing .005 parts acetic acid. The malate of lead separates completely as neutral salt. After standing for 12 or 15 hours filter, wash, dry, weigh, ignite in a porcelain crucible, and weigh as oxide of lead. The loss of weight by ignition is the weight of the malic acid. The organic matter which is mingled with these precipitates is usually so small that it need not be considered. The phosphoric acid is precipitated as phosphate of lead, and comes down with the citrate of lead. This amounts to but a few milligrams, and may be estimated by dissolving the lead oxide after ignition with acetic acid, and deducting what remains from the total weight. This method for extracting these acids, although not all that could be desired, gives fairly good results if carefully managed. It is more satisfactory than any other method that was tried.

Crude ash.—Char 2 to 3 grams of substance at the lowest possible red heat in a muffle, and burn until white, or when by further burning there appears to be no change in the appearance of the ash, taking care not to have heat enough to fuse it.

Ash Analysis.

The ash is burned in the same manner as for the determination of crude ash, thoroughly pulverized in an agate mortar, and preserved in bottles fitted with rubber stoppers.

Solutions.—One gram of ash is weighed into a 6 oz. beaker, and a little water added, covered with a watch glass, and HCl added cautiously until effervescence ceases, then a few drops of HCl added in excess, and the whole evaporated to dryness. The residue is then moistened with HCl, water added and heated on a water-bath for a few minutes, then filtered through a tared Gooch crucible. The residue (sand, silica and carbon) is dried, weighed and ignited. The loss is taken as carbon, and the remainder as sand and silica. The filtrate is made up to 200 c. c. and used in the following determinations:

Sulphuric acid.—Fifty cubic centimeter of the filtrate is made up to 100 c. c. or more, heated to boiling, a boiling solution of barium chloride added, and heated until the supernated liquid is clear; then filtered, washed, dried, ignited, and weighed. The precipitate is barium sulphate, from which the SO_3 is calculated.

Alkalies.—The filtrate from the above is heated to boiling, a slight excess of barium chloride is added drop by drop with constant stirring; without filtering, and in the same manner barium hydrate is added in slight excess. Heat, filter, and wash until precipitate is free of chlorides. Add to the filtrate 1 c. c. of ammonia, and then a saturated solution of ammonium carbonate until the excess of barium

is precipitated. Heat, add now, in fine powder, 0.5 grams pure oxalic acid. Filter, wash free of chlorides; evaporate the filtrate to dryness in a platinum dish, ignite carefully over a free flame below red heat until all volatile matter is driven off. Digest the residue with hot water with a few drops of HCl, filter through a small filter, wash, evaporate filtrate to dryness in a tared platinum dish. Ignite gently at low red heat, and weigh as total alkalies.

Potash.—The residue from the above is taken up with a few drops of HCl and hot water; enough platinic chloride is added to precipitate the chlorides; evaporate until the solution crystalizes upon cooling, treat with 80 per cent. alcohol, wash by decantation, collect in a Gooch crucible, wash with strong alcohol, dry at 100° for thirty minutes, and weigh as $K_2 Pt Cl_6$.

Soda.—Soda is determined by difference between potash and total alkalies.

Lime.—Fifty cubic centimeters of the original solution are made alkaline with ammonia, then acetic acid is added in excess; filter and wash thoroughly. The filtrate is heated nearly to boiling, and ammonia oxalate added in slight excess; continue to heat until the supernated liquid is clear; filter, wash, dry, ignite intensely, and weigh as CaO.

Magnesia.—The last filtrate is made alkaline with ammonia, sodium phosphate added, and allowed to stand for some time; filter, wash with weak ammonia, dry, ignite, and weigh as $Mg_2P_2O_7$.

Phosphoric acid.—Take 50 c. c. of the original solution, neutralize with ammonia, then make slightly acid with nitric acid, add 50 c. c. (more if necessary) molybdic solution, and keep for one hour at the temperature of 65° C. Filter, and wash with ammonium nitrate solution. This filtrate is used for the determination of iron and alumina, described in the next paragraph. The precipitate is dissolved on the filter with dilute ammonia and hot water; the filtrate is nearly neutralized with HCl, and 10 c. c. magnesia mixture is added slowly, with constant stirring; after fifteen minutes add 25 c. c. strong ammonia, and let stand for 2 hours or more; filter, wash with dilute ammonia, ignite, and weigh as $Mg_2P_2O_7$.

Iron and alumina.—The filtrate from the precipitate of ammonium phospho-molybdate is cautiously neutralized with ammonia, care being taken that the temperature does not rise above 40° C., and that the ammonia is only in slight excess. Allow to stand in a warm place until the precipitate completely settles; filter the supernatant liquid, wash the precipitate by decantation, then transfer it to a filter and complete the washing. Redissolve the precipitate in weak nitric acid, reprecipitate, filter, wash, dry, ignite, and weigh as ferric oxide and alumina.

Ferric Oxide.—Dissolve the precipitate of ferric oxide and alumina, reduce with zinc, and determine the ferric oxide with a standard solution of potassium permanganate.

Alumina.—The combined weight of ferric oxide and alumina, minus the ferric oxide obtained, gives the weight of alumina.

Chlorine.—Weigh 5 grams of ash into a beaker, add 100 c. c. of water and a little nitric acid, let stand for one hour, filter, wash, neutralize the filtrate with sodium carbonate, and determine the chlorine with a standard solution of silver nitrate, with the aid of yellow chromate of potash.

Carbonic acid.—One gram of the ash is weighed into a Shepard alkalimeter, a little water added, and the carbonic acid freed with dilute nitric acid, with the aid of a gentle heat, the loss being the carbon dioxide. This method, if properly manipulated, is highly satisfactory.

Insoluble silica, or sand.—Weigh 1 gram into a beaker, add a small quantity of water and hydrochloric acid in excess, heat for some time on a water-bath, filter through a tared Gooch crucible, ignite, and weigh as SiO_2 or sand.

Soluble silica.—The total silica obtained by bringing the solution to dryness before filtering, minus the insoluble silica, gives the soluble silica.

OCCURRENCE OF NITRATES IN TOBACCO.

In nearly all varieties of tobacco a part of the nitrogen is found to exist in the form of nitrate. Just how this form of nitrogen finds its way into the plant has been a disputed question. Some authorities claim that it is a product of decomposition, and the amount may be regulated, to a certain extent, in the process of curing, while others claim that it is taken directly into the plant from the soil through the roots in the process of nutrition, where part or all of it is decomposed to form the other nitrogenous compounds of the plant. From the results of analyses given in the accompanying table it will be seen that the latter theory is more plausible.

The tobacco used in the analyses was the ordinary "bright tobacco" peculiar to certain portions of North Carolina. The seed were sown in the seed-bed, and the plants were transplanted in the field when of proper size. Samples were taken from time to time, commencing at the time the plants were transplanted, and analyses made of the different samples, giving the percentage of nitrogen as nitrate, together with the other forms of nitrogen existing in the different parts of the plant at the different stages of growth. From an inspection of the table it will be noticed that the nitrates are confined almost entirely to the stalk and stems in the younger growth of the plant, while the other nitrogenous substances are more abundant in the leaves. This would indicate that the nitrates had been taken into the plant in the process of nutrition, and used to form the nitrogenous compounds of the rapidly-growing plant, while later the larger plant seems to have consumed the nitrates as fast as they were supplied. These facts lead to one of two conclusions: either the nitrates have, in some mysterious way, passed out of the plant, or the more rational conclusion that the nitrates have been decomposed to form other nitrogenous compounds. In this experiment we have no indication of nitrates being found in the mature tobacco from decomposition in the process of curing. Unfortunately, however, this variety of tobacco is exceedingly free from nitrates as compared with other varieties, as will be seen from the analysis of stems of other varieties.

The methods of analysis used in Table I are those in ordinary use. The total nitrogen was determined by the Kjeldahl method as modified by Scovell to include nitrates. The nitrogen existing as nitrate was determined by the Tiemann Schultze method. The nitrogen existing as nitrate, subtracted from the total nitrogen, gives the organic or nitrogen not in the form of nitrate. All analyses are calculated to the air-dry sample.

TABLE I. EXISTENCE OF NITRATES IN YELLOW TOBACCO AT DIFFERENT STAGES OF GROWTH

Station No.	Part of Plant.	Where Sampled.	When Sampled.	Per ct. Nitrogen existing as Nitrate.	Total Nitrogen not existing as Nitrate.
6007	Roots	From plant-bed	May 29, 1889	None.	2.32
6008	Stalks	" "	" "	0.15	1.83
6009	Leaves	" "	" "	None.	4.22
6010	Stems	" "	" "	0.22	2.11
6011	Roots	From field	June 27, 1889	0.07	2.04
6012	Stalks	" "	" "	0.51	2.01
6013	Leaves	" "	" "	0.09	5.56
6014	Stems	" "	" "	0.77	1.87
6015	Leaves (primed)	" "	" "	None.	3.82
6016	Stems (primed)	" "	" "	0.51	1 43
6017	Roots	" "	July 11, 1889	None.	1.38
6018	Stalks	" "	" "	None.	1.01
6019	Leaves	" "	" "	None.	2.71
6020	Stems	" "	" "	None.	0.99
6021	Leaves (primed)	" "	" "	None.	1.95
6022	Stems (primed)	" "	" "	None.	1.04
6023	Tops	" "	" "	------	4.50
6024	Suckers	" "	July 27, 1889	None.	3.95
6025	"	" "	Aug. 12, 1889	None.	3.57
6026	"	" "	Aug. 31, 1889	None.	3.04
6027	Roots	" "	Sept. 2, 1889	None.	0.99
6028	Stalks	" "	" "	0.03	0.88
6029	Leaves	" "	" "	None.	1 94
6030	Stems	" "	" "	None.	0.69
6031	Roots	From barn	Sept. 9, 1889	None.	1.17
6032	Stalks	" "	" "	Trace.	1.41
6033	Leaves (smokers)	" "	" "	None.	1.98
6034	Stems "	" "	" "	None.	0.69
6035	Leaves (tips)	" "	" "	None.	1.93
6036	Stems "	" "	" "	None.	0.93
6037	Leaves (fillers)	" "	" "	None.	2 17
6038	Stems "	" "	" "	None.	0.80
6039	Leaves (cutters)	" "	" "	None.	2.01
6040	Stems "	" "	" "	None.	0 80
6550	Seed			None.	3.36
6553	Second growth			None.	1.55

Following is a table (II) giving the percentage of both organic and nitric nitrogen in a few samples of tobacco stems analyzed at the Station. It will be observed that the North Carolina stems are very low in nitrates, while the other varieties contain a considerable amount. The percentages of phosphoric acid, and the soluble and insoluble potash are included as matters of interest.

TABLE II. ORGANIC AND NITRIC NITROGEN IN TOBACCO STEMS.

Station Number.	TOBACCOS.	Moisture.	Volatile and Organic Matter.	Crude Ash.	Per ct. Phosphoric Acid.	Per ct. Water Soluble Potash.	Per ct. Total Potash.	Per ct. Water Sol. in Total Potash.	Nitrogen existing as Nitrate.	Total Nitrogen not existing as Nitrate.
5900	Missouri stems for chewing tobacco	16.56	61.65	21.79	.82	8.44	9.08	92.95	0.83	1.69
5901	Kentucky stems for chewing tobacco	16.85	61.69	21.46	.72	8.36	8.89	94.04	0 72	1.66
5902	Ohio stems for chewing tobacco	15.70	62.17	22.13	.84	8.11	8.56	94 63	0.60	2.26
5903	Virginia stems for shipping or export tobacco	16.20	63.72	20.08	.56	6.35	7.00	90.71	0.54	2.05
5904	Virginia stems for shipping or export tobacco	17.15	63.80	19 05	.43	5.25	5.63	93.25	0.13	1.64
5905	North Carolina stems for cigarettes	18.18	65.86	15.96	.51	4.97	5.33	93.15	0.00	0.77
5906	North Carolina stems for cigarettes short	15.90	65.80	18 30	.58	4.11	4.19	98.09	0.15	1.26
5907	Stalk of bright N. C. tobacco	17 36	71.78	10.86	.52	3.92	4.34	90.32	0.05	1.68
5923	North Carolina stems for chewing tobacco before casing	16.75	67.40	15.85	.73	3.37	3.66	92.08	0.00	.98
5924	North Carolina stems for chewing tobacco after casing*	12.42	70.29	17.29	.43	4 27	4.55	93.84	0.07	1.43
5926	North Carolina dust from smoking tobacco factory, poor sample	9.04	48.68	42 28	.87	1.67	1.97	84.77	0.00	1.23

*This sample being wet when received, was air-dried, which accounts for the increased percentage.

DESCRIPTION OF THE TOBACCO SOIL.

The soil upon which this tobacco was grown is a light-gray sand, with porous cream-colored subsoil. This soil belongs geologically to the Laurentian series of the Archæan era, which formation seems to be peculiarly adapted for the production of the yellow tobacco for which Granville county, N. C., has become famous. The tobacco soil, the analysis of which is given below, was not from the same field in which the experiment tobacco grew, yet was from the same locality, about two miles distant, and represents very closely the general character of the best bright tobacco soil. This sample was taken from a field of about 30 acres, owned by Mr. J. M. Currin, Oxford, N. C.

The land was cleared about ten years previous and was cultivated for four or five years, since which time it has not been in cultivation until the summer of 1892, when a fine crop of tobacco was grown. The fertilizers used on the soil for this crop consisted of a light coat of stable manure and 1,000 pounds of commercial fertilizer to the acre. Mr. Currin considers this a typical tobacco soil:

	Top soil.	Subsoil.
Coarse materials	7.05	3.95
Fine earth	92.95	96.05
	100.00	100.00
Analysis of Fine Earth:		
Insoluble matter	95 642	94.870
Soluble silica	.938	1.476
Potash (K_2O)	.161	.057
Soda (Na_2O)	.109	.232
Lime (CaO)	.240	.265
Magnesia (MgO)	.047	.056
Peroxide of iron (Fe_2O_3)	.326	.488
Alumina (Al_2O_3)	1.038	1.872
Phosphoric acid (P_2O_5)	.016	.000
Sulphuric acid (SO_3)	.055	.072
Water (H_2O)	.312	.286
Volatile matter	1.510	1.050
	100.394	100.724

ORGANIC ANALYSES IN DETAIL.

The plans and details of the experiment for comparing the curing of tobacco by the leaf-cure and the stalk-cure, and also the results with reference to the amount and value of the tobacco as affected by the two methods of curing, were fully set forth in Bulletin 86. For convenience, the tables giving the amount and money value of each grade from each method of curing, is here reprinted.

TABLE III. RESULT OF THE EXPERIMENT.

1.—*Tobacco Curing on the Stalk from Half-acre.*

Mark.	Grade.	Weight in Pounds.	Value, Estimated by Experienced Buyers, Per 100 Pounds.						Actual Sale.	Total Value.
			Z. W. Lyon.	J. G. Hunt.	E. T. White.	J. M. Currin.	J. H. Bullock.	Av. of the five.		
	Smokers.									
A	Scrap from stalk	6.50	$ 3.50	$ 4.00	$ 4.00	$ 5.00	$ 4.00	$ 4.10	$ 4.00	$ .2665
C	Scrap	15.75	2.50	3.00	2 50	3.00	2.75	2.75	3.00	.4331
D	Trash lug	49.	3.50	5.00	3.40	4.00	5.00	4.18	4.00	2.0482
F	Best lug	18.75	10.00	10.00	9.00	8.00	8.00	9.00	9.00	1.6875
	Cutters.									
I	Sand lug	63.75	15.50	14.00	16.00	15.00	12.00	14.50	14.00	9.2437
K	Best lug	16.75	15.00	17.00	15.00	15.00	15.00	15.40	20.00	2.5795
	Wrappers.									
M	First grade	50.	18.00	20.00	16 00	18.00	20.00	18.40	14.25	9.2000
N	Second grade	54.	13.50	15.00	14 00	13.00	14.00	13.90	13.00	7.5060
	Fillers.									
P	Bright tips	47.	10.00	12.00	10.75	9.00	11.00	10 55	10.75	4.9585
S	Black tips	4.75	7.75	9.00	7.00	7.50	7.50	7.75	9.00	.3681
	Total	326.25	Average value per 100 pounds, $11.74.						Total.	$38.29

2.—*Tobacco Curing by the Leaf Process on Wire from Half-acre.*

Mark.	Grade.	Weight in Pounds.	Value, Estimated by Experienced Buyers, Per 100 Pounds.						Actual Sale.	Total Value.
			Z. W. Lyon.	J. G. Hunt.	E. T. White.	J. M. Currin.	J. H. Bullock.	Av. of the five.		
	Smokers.									
B	Scrap	13.50	$ 3.00	$ 3 20	$ 3.50	$ 3.00	$ 3.00	$ 3.14	$ 3.10	$ .4239
E	Trash lug	34.75	6.00	6.00	5.00	5 00	6.00	5.60	6.00	1.9460
G	Best trash lug	31.75	12.50	12.50	12.50	12.00	10.00	11.90	12.00	3.7782
	Cutters.									
H	Sand lug	104.	16 50	16.00	17.50	14.00	16.00	16.00	16.75	16.6400
J	Best lug	40.	15.00	18.00	17.00	18.00	15.00	16.60	20.00	6.6400
	Wrappers.									
L	First grade	90.	20.00	20.00	20 00	20.00	22.00	20.40	20.00	18.3600
O	Second grade	55.	11.50	16.00	16 00	12.00	14.00	13.90	14.00	7.6450
	Fillers.									
Q	Bright tips	56.25	8.25	12.00	10.00	11.00	8.00	9.85	9.25	5.5406
R	Black tips	28.75	7.00	8.50	8.00	7.00	7.00	7.50	7.50	2 1663
	Total	454.	Average value per 100 pounds, $13.91.						Total.	$63.14

Having thus compared in a commercial way the two methods of curing, it was thought desirable to continue the experiment, and see if there was any material difference in the chemical composition of the two lots of tobacco resulting from the two processes. Samples

were taken from each grade mentioned in the preceding table, packed in a tight box, and sent to the laboratory. The stems were then separated from the leaf, and the samples allowed to become thoroughly air-dry on a dry day. These samples (stems and leaves separately) were ground until they would pass a No. 36 sieve, and preserved in tight jars for analysis. Partial analyses were made of all the samples representing the different grades, and more complete analyses of a few samples representing the same grade by both processes of curing.

The following tables give the results of the analyses, which are tabulated in such a way as to admit of easy comparison:

TABLE IV. ANALYSES OF WHOLE TOBACCO LEAVES (AIR-DRIED). CALCULATED FROM THE DIRECT ANALYSES OF MIDRIB AND LEAVES (EXCLUSIVE OF MIDRIB).

1. Cured by the Stalk Process.

MARK.	GRADE.	Leaf without stem.		Stems.		Whole leaf		Nicotine.		Resin and fatty substances.		Albuminoids.		Nitric acid		Ammonia.		Cellulose.		Moisture.		Ash.		Sand.		Ash exclusive of sand	
	Smokers.	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct	Pr	Ct
A	Scrap from stalk	....		....		....		2.53		9.45		9 06		0		.122		9.28		6 19		14.37		2.79		11.58	
C	Scrap	86.1		13.9		100		1 80		6.88		5.92		0		.107		9.38		6.88		18.58		7.11		11.47	
D	Trash lug	80.6		19.4		100		1 84		6.73		5.03		0		.118		9.66		9.14		14.46		1.87		12.59	
F	Best lug	78.		22.		100		1.85		6.70		5.90		0		.099		9.27		8.74		12.65		1.23		11.42	
	Cutters.																										
I	Sand lug	80.		20.		100		2.16		7 64		6.07		0		.107		8.89		6.58		12.42		.38		12.04	
K	Best lug	80 6		19.4		100		2.43		6.88		5.80		0		.100		8.80		7.42		11.87		.40		11.47	
	Wrappers.																										
M	First grade	79.6		20.4		100		2.48		6.65		6 38		0		.116		8 55		8.84		11.32		.44		10.88	
N	Second grade	81.2		18.8		100		2·49		6.77		6.20		0		.113		8.61		8.06		11.03		.31		10.72	
	Fillers.																										
P	Bright tips	83.2		16.8		100		2.49		7.08		7.01		0		.127		8.40		8.76		9.87		.73		9.14	
S	Black tips	79.4		17.9		100		1.86		6.56		7.39		0		.109		8 63		7.56		9.83		.54		9.29	
W*	Leaves for comparis'n	79.		21.		100		2 31		6.24		6.81		0		.102		7.93		7 47		10.83		.23		10 60	

2. Cured by the Leaf Process on Wire.

	Smokers.																										
B	Scrap	82.7		17 3		100		1.90		5.24		5.92		0		.125		9.84		7.68		22.23		9 62		12.61	
E	Trash lug	78.3		21.7		100		1.75		5.66		5.31		0		.109		9.38		7.52		18.72		5.51		13.21	
G	Best trash lug	80.3		19.7		100		1.91		6.33		6.32		0		.126		8.90		8.47		15.08		3.13		11.95	
	Cutters.																										
H	Sand lug	82.5		17.5		100		2.05		6.35		6.59		0		.122		8.88		7.81		14.12		2.67		11.45	
J	Best lug	78.6		21.4		100		2.00		6.41		6.44		0		.119		8.54		8.46		13.68		1.90		11.78	
	Wrappers.																										
L	First grade	79.9		20.1		100		2.18		6 16		5 97		0		.141		8.76		7.95		14.02		2.81		11.21	
O	Second grade	82.6		17.4		100		2.55		6.22		8.15		0		.127		8.99		9.49		11.50		.50		11.00	
	Fillers.																										
Q	Bright tips	83.2		16 8		100		2.60		6.35		8 82		0		.148		8 79		8 27		10.07		.36		9.71	
R	Black tips	82.1		17.9		100		2.60		4.96		10.10		0		.161		8.44		9.54		11.05		.46		10.59	
X*	Leaves for comparis'n	78.1		21 9		100		2.24		5.88		6.67		0		.119		7.88		8 19		10 37		21		10.16	

*For descriptions of samples "X" and "W" see page 23.

It will be observed from the tables that the lower grades by the leaf-cure contained a much larger amount of sand than those by the stalk-cure. This is due to the fact that these lower grades are the leaves nearest the ground, and naturally collect sand by the action of rain upon the soil adjacent to the leaves. They were all pulled by the leaf process as they ripened, while in the stalk process many of the lower leaves, together with the sand contained on them, had fallen off before the time for harvesting. This inequality in the percentage of sand made it necessary to calculate the samples to a sand-free as well as water-free basis for a full comparison. (See tables V, VI and VII.) Table VII combines the two preceding tables, and presents, by calculation, the composition of the whole leaf, including midrib.

TABLE V. ANALYSES OF TOBACCO LEAVES (EXCLUSIVE OF MIDRIB) REDUCED TO A SAND-FREE AND WATER-FREE BASIS.

Station No.	Grade Mark	Grade of Leaves.	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid.	Ammonia.	Cellulose.	Ash.
				1.—*Cured by the Stalk Process.*					
1	A	*Smokers*—Scrap from stalk	2.78	10.38	9.32	0	.134	10.18	12.72
3	C	Scrap	2.32	8 80	6.85	0	.139	9.15	12.86
4	D	Trash lug	2 42	8 76	6.19	0	.146	8 70	12.92
6	F	Best lug	2.49	8.85	7.29	0	.117	7.54	11.32
9	I	*Cutters*—Sand lug	2.78	9.63	7.28	0	.123	7.30	11.67
11	K	Best lug	3.14	8.75	6.72	0	.112	7.01	11.16
13	M	*Wrappers*—First Grade	3.24	8.35	7.60	0	.131	7.09	10.60
14	N	Second Grade	3.22	8.71	7.21	0	.130	8 68	10.46
16	P	*Fillers*—Bright tips	3.20	9.04	8.20	0	.149	7.09	9.13
19	S	Black tips	2.39	8.23	8.67	0	.123	6.92	8.91
20	W	Leaves for comparison	3.02	8.18	8.15	0	.121	6.34	9.69
				2.—*Cured by the Leaf Process on Wire.*					
2	B	*Smokers*—Scrap	2 67	7.19	7.46	0	.162	10.16	14.73
5	E	Trash lug	2.41	7.74	6.41	0	.132	8.66	13.92
7	G	Best trash lug	2.56	8.50	7.78	0	.152	8.01	12.54
8	H	*Cutters*—Sand lug	2.65	8.26	7.86	0	.143	8.13	11.78
10	J	Best lug	2.72	8.55	7.87	0	.141	7.36	11.93
12	L	*Wrappers*—First grade	2.96	8.25	7.17	0	.167	7.30	11.07
15	O	Second grade	3.32	8.00	9.87	0	.149	7.81	11.14
17	Q	*Fillers*—Bright tips	3.30	7.97	10.42	0	.171	7.68	9.65
18	R	Black tips	3.35	6.36	12.31	0	.192	7.39	10.63
21	X	Leaves for comparison	2.96	7.79	7.82	0	.146	6.46	9.07

TABLE VI. ANALYSES OF TOBACCO STEMS (OR MIDRIB) REDUCED TO A SAND-FREE AND WATER-FREE BASIS.

Station No.	Grade mark	Grade of Leaves.	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid.	Ammonia.	Cellulose.	Ash.
				1.—*Cured by the Stalk Process.*					
22	A	*Smokers*—Scrap from stalk	--	----	----	-	----	-----	-----
24	C	Scrap	.73	3.36	6 86	0	.045	21.13	16.24
25	D	Trash lug	.61	2.70	3.41	0	.081	19.64	19.10
27	F	Best lug	.54	2 48	3.90	0	.084	20.05	17.48
30	I	*Cutters*—Sand lug	.48	2.51	4.08	0	.083	18.63	18.04
32	K	Best lug	.52	2.10	4.52	0	.094	20.07	17.77
34	M	*Wrappers*—First grade	.72	3.32	4.82	0	.114	18.53	17.41
35	N	Second grade	.54	1.67	4.82	0	.094	20.39	17.02
37	P	*Fillers*—Bright tips	.64	1.93	5.45	0	.101	20.13	15.03
40	S	Black tips	.64	2.98	5.57	0	.106	18.88	14.70
41	W	Leaves for comparison	.53	1.41	4 45	0	.070	17.06	18.13
43		Stalks from plants	.77	.96	8.21	0	.118	29.35	8.74
				2.—*Cured by the Leaf Process on Wire.*					
23	B	*Smokers*—Scrap	.72	2.67	5.52	0	.102	19.40	17.46
26	E	Trash lug	.64	2.27	4.92	0	.106	18.10	19.17
28	G	Best trash lug	.57	1.90	4.49	0	.108	18.20	17.58
29	H	*Cutters*—Sand lug	.58	1.78	4.99	0	.110	18.25	17.48
31	J	Best lug	.49	2.08	4.66	0	.101	17.46	17.47
33	L	*Wrappers*—First grade	.49	1 74	4.72	0	.120	19.57	18.42
36	O	Second grade	.54	1.74	5.21	0	.104	20.28	17 38
38	Q	*Fillers*—Bright tips	.63	1.86	5.82	0	.119	19 22	15.52
39	R	Black tips	.71	1.57	6.21	0	.119	19.08	16.98
42	X	Leaves for comparison	.57	1.48	5.32	0	.078	16.27	18.32
44		Stalks from plants	.77	.82	7.21	0	.099	31.20	9.31

TABLE VII. ANALYSES OF WHOLE TOBACCO LEAF (INCLUDING MIDRIB). CALCULATED TO A SAND-FREE AND WATER-FREE BASIS.

Grade Mark.	GRADE OF LEAVES.	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid.	Ammonia.	Cellulose.	Ash.
		1.—Cured by the Stalk Process.						
A	*Smokers*—Scrap from stalk	2 78	10.38	9.95	0	.134	10.19	12.72
C	Scrap	2.09	8.00	6.88	0	.124	10.91	13.34
D	Trash lug	2.07	7.56	5.65	0	.133	10.86	14.15
F	Best lug	2.05	7.44	6.55	0	.110	10.30	12.68
I	*Cutters*—Sand lug	2.32	8.21	6.52	0	.115	9.56	12.94
K	Best lug	2.64	7.46	6.29	0	.109	9.55	12.44
M	*Wrappers*—First grade	2.73	7.33	7.03	0	.129	9.42	11.99
N	Second grade	2.72	7.39	6.77	0	.123	9.40	11,70
P	*Fillers*—Bright tips	2.75	7.82	7.75	0	.140	9.28	10.10
S	Black tips	2.02	7.14	8.04	0	.119	9.39	10.70
W	Leaves for comparison	2.50	6.76	7.38	0	.111	8.59	11.48
		2.—Cured by the Leaf Process on Wire.						
B	*Smokers*—Scrap	2.30	6.34	7.16	0	.151	11.90	15.25
E	Trash lug	2.01	6.51	6.11	0	.125	10.79	15.19
G	Best trash lug	2.16	7.16	7.15	0	.143	10 07	13.52
H	*Cutters*—Sand lug	2.29	7.09	7.36	0	.136	9.92	12.79
J	Best lug	2.23	7.15	7.18	0	.133	9.53	13.14
L	*Wrappers*—First grade	2.44	6.90	6.69	0	.157	9.82	12.56
O	Second grade	2.83	6.91	9.05	0	.141	9.99	12.22
Q	*Fillers*—Bright tips	2 85	6.95	9.65	0	.151	9.62	10.63
R	Black tips	2.88	5.51	11.22	0	.179	9 38	11.77
X	Leaves for comparison	2.45	6.42	7.28	0	.130	8.60	11.09

The samples "X" and "W" represent fair samples of tobacco from the same plants, cured as follows: Thirty plants, which had an even number of leaves, were selected from the field, the alternate leaves stripped off from each plant, and strung on wire. The number of leaves on the wire was 129, and the same number were left on the stalk. Both the plants containing the remaining leaves and the leaves on the wires were then hung side by side in the Snow barn and cured with other tobacco. The samples by both processes were taken down, the leaves stripped from the stalk, and the leaves from both methods were weighed with these results:

Leaf-curing process	62½ oz.
Stalk-curing process	58½ oz.
Excess over stalk process	4 oz.

This experiment was suggested by the claim of the Snow Barn Co., that leaves cured by their process would weigh more than when cured on the stalk. It is true that the leaves cured on wire weighed a very little more in this case, but as there was so small a quantity of leaves tested, and only one trial, it is not safe to draw conclusions. The small variation might possibly have resulted from an excess

of moisture only. The analysis of these samples shows no material difference in the composition, and as they represent samples of like growth, etc., the results are valuable in drawing conclusions in the principal experiment.

A complete consideration of the difference between the processes of curing, especially in reference to the chemical composition of the leaves as affected by the two methods, requires that we begin with the tobacco as it stood in the field before any of the harvesting had been done, for the reason that the manner and times of harvesting were quite different. By the stalk-curing process many of the lower leaves became ripe and dropped off before the plant was considered ripe enough to cut. When the plant was harvested some of the lower leaves were over-ripe, while the tips were still green.

By the leaf-curing process this difficulty was overcome to a certain extent. The leaves which would have been lost by the stalk process were saved by priming them off as they became ripe. The remaining leaves were primed in like manner until the whole plant, except the stalk, was harvested, which in this case was accomplished with three primings. The first priming by the leaf-cure took place August 17, the second September 1, and the third September 14. By the stalk-curing process all the tobacco was cut September 15, making nearly a month from the first priming by the leaf-curing process. Thus it will be seen that there was quite a difference in the time of harvesting by the two methods, which must necessarily have its effect upon the results.

By the leaf-curing process, the priming of the lower leaves has a tendency to renew the growth of the remaining leaves, which becomes very marked in case of the tip leaves. The analysis of these tip leaves shows a large increase in nitrogenous matter and nicotine compared with the stalk-cure. This would indicate a stronger and somewhat inferior quality of tobacco in case of these leaves, but the gain in weight more than compensates for the loss in quality. Aside from the tips there are no very marked variations in composition resulting from the two methods of curing. The slight difference noticed is probably due to the time and manner of harvesting to which reference has been made.

It will be noticed that the ash by the leaf-curing process is somewhat higher than by the stalk process. After the leaves of the tobacco plant, as with most other plants, arrive at a certain stage of growth, the tendency is for the percentage of ash to decrease if the plant is allowed to stand. As the difference in this case is most noticeable in the lower grades, representing the lower leaves, it is likely that this difference is largely due to the condition of the leaf when harvested. The same may be said of the organic nitrogenous substances, which are noticed to be slightly higher by the wire-curing process. This is particularly noticeable in case of the black tips, which in the wire-curing process have had the whole stalk to feed upon, developing a coarser and heavier leaf with a large increase of albuminoids

With reference to the resins and fatty substances, there seems to be a slight difference in favor of the stalk-cure. A noticeable feature in this connection is the large percentage of resins and fatty substances in sample A, representing the scrap from the stalk. This scrap consists of the extensions or wings of the leaf, which are attached to the stalks at the base of the leaf. It will also be seen that this sample is rich in nicotine and albuminoids. This sample cannot be considered in the comparison, as it was not saved by the wire-curing process.

The analysis of the different grades shows that a considerable variation is found in the leaves from different parts of the plant. Some of the variations found by comparing the two processes of curing can be accounted for from the fact that like grades by the different processes do not consist of leaves from the same portions of the plant.

The analyses of samples "X" and "W," with reference to the merits of curing the stalk with the leaf, and curing the leaf separate from the stalk, but having all the other conditions as nearly alike as possible, shows no material difference in the results. The more complete organic analyses of samples L and M (first grade wrappers) found in table VIII, including leaf, stem and stalk, are of interest as such, but with reference to this experiment there is nothing to change the observations already noted. One of the most remarkable features of this variety of tobacco is the large percentage of carbohydrates, especially that of glucose, which in this case reaches 17.54 per cent. of the whole leaf. This glucose in the stem by the leaf-curing process is considerably higher than by the stalk-process, while the reverse is true in case of the stalk. While it is true that glucose is the most liable to change of all the constituents of tobacco in the process of curing, it is believed that the differences are due in this case to the time and methods of harvesting.

TABLE VIII. ORGANIC ANALYSES OF TOBACCO DRIED AT 100° C. MORE COMPLETE THAN IN PRECEDING TABLES.

Station number.	Grade mark.	Description.	Nicotine.	Resin and fatty substances.	Starch.	Glucose.	Albuminoids (N×6.25).	Pectic acid (anhydride).	Citric acid (anhydride).	Malic acid (anhydride).	Oxalic acid (anhydride).	Acetic acid (anhydride).	Nitric acid (anhydride).	Ammonia.	Cellulose (crude fiber).	Sand.	Ash.	Undetermined.	Total.
								1.—*Cured by the Stalk Process.*											
13	M	Leaf	3.23	8.31	6.35	19.05	7.56	5.63	1.22	8.21	1.23	.44	.00	.131	7.05	.56	10.54	20.49	100
34	M	Stem	.72	3.31	5.86	11.65	4.81	10.49	.33	5.23	2.04	.19	.00	.113	18.49	.21	17.37	19 19	100
	M	Whole leaf, First Grade Wrapper	2.72	7.29	6.25	17.54	7.00	6.62	1.04	7.59	1.62	.39	.00	.127	9.38	.49	11.93	20.03	100
43		Stalk	.77	.96	11.42	10.50	7.99	3.83	.29	1.05	1.28	.19	.00	1.18	29.29	.18	8.73	22.39	100
								2.—*Cured by the Leaf Process on wire.*											
12	L	Leaf	2.84	7.94	5.13	18.08	6.94	4.72	.95	7.64	1.39	.48	.00	.161	7.03	3.62	10.66	22.42	100
33	L	Stem	.49	1.72	5.70	14.56	4.69	10.04	.27	4.32	1.71	.24	.00	.119	19.43	.75	18.27	17.69	100
	L	Whole leaf, First Grade Wrapper	2.37	6.69	5.24	17.37	6.49	5.79	.81	6.97	1.45	.43	.00	.153	9.52	3.05	12.18	21.49	100
44		Stalk	.77	.82	11.56	7.41	7.19	3.97	.26	1.30	1.47	.11	.00	.99	31.10	.32	9.29	23.44	100

ASH ANALYSES.

For further comparison, the following complete ash analyses (table IX), were made of samples L and M (first grade wrappers), including the leaf, stem and stalk. The large percentage of insoluble silica in No. 12 indicates that many of the lower leaves, having a large percentage of sand adhering, were used as wrappers by the Snow process, which were either lost or unsuitable for this grade in the stalk process.

TABLE IX. ASH ANALYSES OF TOBACCO.

Station Number.	Grade Mark.	Part of tobacco analyzed.	Total Ash.	Total ash exclusive of sand, carbon and carbonic anhydride.	Potash.	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Phosphoric acid.	Sulphuric acid.	Chlorine.	Carbonic acid.	Soluble silica.	Insoluble silica.	Carbon.	Minus oxygen equivalent of chlorine.	Total.
12	L	Leaf	14.28	8.51	13.48	.35	25.76	5.39	.23	1.87	3.36	4.20	4.50	14.49	1.29	25.34	.59	1.02	99.93
13	M	Leaf	11.10	8.09	20.32	.94	30.08	5.80	.50	1.18	3.88	6.08	4.56	21.76	.89	5.08	.30	1.03	100.34
33	L	Stem	19.02	15.38	27.16	.91	23.68	7.47	.65	.91	4.00	3.96	15.85	14.48	.84	4.00	.67	3.59	100.99
34	M	Stem	17.58	14.30	27.64	.87	23.88	7.74	2.05	.47	4.22	4.20	13.42	17.05	.68	1.18	.47	3.04	100.83
43		Stalk	8.91	7.49	27.08	.82	23.92	7.16	.33	.79	5.96	7.29	11.78	13.79	.97	1.92	.25	2.66	99.40
44		Stalk	9.61	7.94	28.08	.79	21.96	7.06	.65	.91	4.96	7.90	11.85	13.90	.92	3.28	.21	2.68	99.79
	L	Whole leaf	15.23	9.89	16.23	.46	25.34	5.81	.39	1.68	3.48	4.15	6.78	14.48	1.20	21.05	.60	1.54	100.14
	M	Whole leaf	12.42	9.35	21.81	.93	28.71	6.19	.82	1.03	3.95	5.70	6.37	20.80	.85	4.28	.33	1.44	100.33

Table X represents the preceding table calculated on a different basis, and consists of the proportion of mineral ingredients contained in 100 parts of the ash exclusive of sand, carbonic acid, and carbon.

Table XI shows the proportion of mineral ingredients and nitrogen content in 100 parts of the tobacco dried at 100° C. While in general there are no large differences in the percentage of ash constituents by the leaf and stalk cures, there are some quite marked variations.

The percentage of potash in the whole leaf by the leaf-cure is several per cent. less than by the stalk-cure, while the reverse is true in the case of chlorine. It is known that the amount and composition of the ash is constantly changing during the growth of the tobacco plant. There is, also, a marked variation in the leaves of different portions of the plant. It is probable, therefore, that the variations may be due to these causes.

The first priming for the leaf-cure took place about a month previous to the cutting for the stalk-cure, and many of the leaves from the first and second priming were classed with the best grades, but were lost or damaged in the stalk-cure The priming of the lower leaves also changes the character of those remaining to a certain extent by causing an increased growth.

TABLE X. PERCENTAGE COMPOSITION OF ASH OF TOBACCO, EXCLUSIVE OF SAND, CARBONIC ACID, AND CARBON.

Station No.	Grade mark.	DESCRIPTION OF SAMPLE.	Potash.	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Silica.	Minus oxygen equiv. of Cl.	Total.
12	L	Leaf—Leaf-cure	22 66	.59	43.29	9.06	.55	3.14	5.64	7.06	7 56	2.17	1.72	100
13	M	Leaf—Stalk-cure	27.75	1.29	41.09	7 92	.69	1.61	5.31	8.30	6.23	1.22	1.41	100
33	L	Stem—Leaf-cure	33.19	1.11	28.94	9.13	.79	1.11	4 89	4.84	19.38	1.02	4.39	100
34	M	Stem—Stalk-cure	33.65	1.06	29.07	9 42	2.49	.58	5 14	5.12	16.34	.83	3.70	100
43		Stalk—Stalk-cure	32.46	.99	28.67	8 58	.39	.95	7.14	8 73	14 12	1.16	3.19	100
44		Stalk—Leaf-cure	34.05	.96	26 63	8 56	.79	1.10	6.01	9.58	14.37	1.11	3.24	100
	L	Whole leaf—Leaf-cure	25.37	.72	39.60	9.08	.61	2.63	5.44	6.49	10.59	1.88	2.41	100
	M	Whole leaf—Stalk-cure	29.10	1.24	38.32	8.27	1.09	1.38	5.27	7.60	8.51	1.14	1.92	100

TABLE XI. PROPORTION OF MINERAL INGREDIENTS AND TOTAL NITROGEN IN 100 PARTS OF TOBACCO, DRIED AT 100° C.

Station No,	Grade mark.	DESCRIPTION OF SAMPLE.	Potash,	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Phosph'cacid.	Sulph'ricacid	Chlorine.	Silica.	Minus oxygen equiv. of chlorine.	Tot. mineral ingredients.	Tot. nitrogen.
12	L	Leaf—Leaf-cure	1.93	.05	3 68	.77	.05	.27	.48	.60	.65	.18	.15	8.51	1.79
13	M	Leaf—Stalk-cure	2 24	.10	3.32	.65	.06	.13	.43	.67	.50	.10	.11	8.09	1.88
33	L	Stem—Leaf-cure	5 11	.17	4 45	1 40	.12	.17	.75	.74	2.98	.16	.67	15.38	.95
34	M	Stem—Stalk-cure	4.81	.15	4.16	1.35	.36	.08	.74	.73	2.33	.12	.53	14 30	.98
43		Stalk—Stalk-cure	2 43	.07	2.15	.64	.03	.08	.53	.65	1.06	.09	.24	7 49	1.54
44		Stalk—Leaf-cure	2.71	.08	2.11	.68	.06	.09	.48	.76	1 14	.09	.26	7 94	1.37
	L	Whole leaf—Leaf-cure	2.50	.07	3.92	.90	.06	.26	.54	.64	1.05	.19	.24	9 89	1.62
	M	Whole leaf—Stalk-cure	2.72	.12	3.58	.77	.10	.13	.49	.71	.80	.11	.18	9.35	1.70

ANALYSES OF AMERICAN TOBACCOS.

The following analyses (tables XII and XIII), taken from very complete report* on The Production of Tobacco in the United States, in the Tenth Census, represent the composition of the principal varieties of tobacco grown in different portions of the United States, analyzed by Dr. G. E. Moore. They are inserted to lend additional interest to the previous tables of analyses.

*Tenth Census. "Statistics of Agriculture," p. 269.

TABLE XII. PERCENTAGE COMPOSITION OF TOBACCOS, DRIED AT 100° C.

Number of sample.	VARIETY.	Nicotine.	Resin and fatty substances.	Starch.	Glucose.	Albuminoids (N×6.25).	Pectic acid (anhydride).	Citric acid (anhydride).	Malic acid (anhydride).	Oxalic acid (anhydride).	Acetic acid (anhydride).	Nitric acid (anhydride).	Ammonia.	Cellulose (crude fiber).	Sand.	Ash, exclusive of sand and carbonic acid.	Undetermined.	Total.
3	Virginia; sun-cured; for manufacturing plug tobacco.	3.26	4.15	5.89	6.89	16.09	6.19	2.12	5.02	0.84	0.42	0.00	0.33	9.58	0.55	12.41	26.26	100
5	Virginia; fire-cured; for German and continental trade; low grade.	4.30	4 65	2.75	2.75	13.66	7.46	2.84	7.58	1.03	0.55	0.00	0.32	9.24	2.38	13.36	27.13	100
7	Tennessee, Clarksville; fire-cured; gummy; for German and English markets; soil: heavy, rich loam.	5.29	4.99	3.54	0.00	16.54	6.01	2.99	5.51	1.30	0.39	1.55	0.98	9.68	2.25	14.37	24.61	100
19	Kentucky, Mason Co.; air-cured; for cutting or plug tobacco.	3.12	5.34	4.45	0.00	15.98	7.49	4.05	9.26	2.18	0.64	0.00	0.48	12.18	0.66	16.06	18.11	100
10	North Carolina, Granville Co.; bright wrapper; grown on white or light gray sand.	2.70	5.73	6.71	16.39	8.75	5.97	0.43	7.41	0.46	0.53	0.00	0.19	9.13	1.26	8.49	25.85	100
28	Louisiana "Perique" tobacco; "cured in its juices."	4.32	6.28	2.45	0.00	15.80	6.66	1.18	3.94	3.49	1.62	0.00	0.76	9.08	4.17	13.30	26.95	100
37	Louisiana "Perique" tobacco; air-cured.	4.25	7.26	2.79	0.00	16.50	7.43	4 31	7.90	2.06	0.28	1.65	1.65	8.30	0.76	15.54	19.32	100
35	Connecticut seed-leaf, New Milford; soil: rich loam.	4.06	4.29	3.22	0.00	18.09	6.29	5.80	10.09	0.92	0.31	3.23	0.65	10.61	1.34	15.10	16.00	100
30	Connecticut seed-leaf, Hartford; sandy soil.	1.14	2.93	3.14	0.00	17.33	11.24	4.95	5.04	0.95	0.48	2.39	0.62	15.23	1.48	18.56	14.52	100
34	Penn. seed-leaf; Lancaster Co.,	1.04	4.02	3.67	0.00	14.62	12.59	1.61	5.46	0.94	0.57	0.00	0.22	15.12	1.64	17.98	20.52	100
16	Ohio seed-leaf	1.92	3.87	3.19	0.00	15.30	7.46	3.46	6.58	1.42	0.42	3.41	0.92	12.87	1.85	14.22	23.11	100
22	New York State seed-leaf	2.35	3.02	2.63	0.00	16.26	9.89	4.42	8.27	1.11	0.41	2.29	1.20	12.15	1.94	15.50	18.56	100
25	Wisconsin and Illinois seed-leaf	0.86	3.28	4.15	0.00	20.34	11.61	2 99	6.88	1.07	0.68	1.22	0.63	12.97	1.53	15.43	16.36	100

TABLE XIII. ASH ANALYSES.

Number of sample.	VARIETY.	Total ash.	Ash, exclusive of sand and carbonic anhydride.	Potash.	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Manganous oxide.	Phosphoric anhydride.	Sulphuric anhydride.	Silicic anhydride.	Chlorine.
3	Virginia; sun-cured; for manufacturing plug tobacco.	14.29	12.41	34.16	0.26	31.76	7.91	0.58	1.22	0.00	3.81	4.99	1.39	13.92
5	Virginia; fire-cured; for the German and continental trade; low grade.	17.42	13.36	26.55	0.22	36.96	11.51	0.95	1.81	0.00	3.23	4.27	3.29	11.21
7	Tennessee, Clarksville; fire-cured; gummy; for the German and English markets; soil: heavy, rich loam.	19.23	14.37	33.15	0.15	36.48	11.85	0.51	0.95	0.25	4.42	6.16	3.42	2.66
19	Kentucky, Mason county; air-cured; for cutting or plug tobacco.	21.85	16.06	39.51	0.86	39.80	5.34	1.56	0.51	0.13	6.09	4.52	1.20	0.48
10	North Carolina, Granville county; bright wrapper; grown on white or light gray sand.	11.19	8.49	41.56	0.47	28.12	9.78	0.59	0.29	0.11	5.23	4.53	2.75	6.57
37	Louisiana "Perique" tobacco; air-cured (leaf deprived of midrib).	19.82	15.54	30.23	0.25	37.47	12.43	1.19	0.72	0.29	6.18	6.19	1.91	3.14
35	Connecticut seed-leaf, New Milford; soil: rich loam.	21.08	16.30	35.08	0.01	40.38	11.33	1.47	0.74	0.13	3.20	4.08	1.39	2.19
30	Connecticut seed-leaf, Hartford; sandy soil	22.92	18.56	41.30	0.26	28.70	7.56	2.13	0.83	0.00	3.26	3.34	1.09	11.58
34	Pennsylvania seed-leaf; Lancaster county	24.74	17.98	49.60	0.36	28.55	8.18	1.39	1.05	0.00	5.72	2.61	1.05	1.49
16	Ohio seed-leaf	19.95	14.22	33.37	0.27	34.69	17.32	1.07	0.93	trace	4.29	3.48	3.07	1.51
22	New York State seed leaf	21.12	15.50	33.13	0.39	39.26	8.60	0.74	0.56	0.16	3.61	3.78	3.67	6.10
25	Wisconsin and Illinois seed-leaf	20.81	15.43	38.71	1.08	33.49	12.57	0.79	0.74	trace	3.09	3 89	4.65	0.99

CONCLUSIONS.

1. In arriving at conclusions in this experiment it is necessary to distinguish between the immediate effects of the curing and the effect that the priming, time of harvesting, etc., have had on the quantity and quality of tobacco produced. On account of the great diversity in the character and composition of different vareties of tobacco, together with the various methods employed in curing, these conclusions can only apply to yellow tobacco and varieties similar to it, when cured according to the methods employed in this experiment.

2. The larger amount of tobacco obtained by the leaf-curing process resulted both from saving all the lower leaves when at their best, and an increased growth of the upper part of the plant, caused by priming the lower leaves.

3. The superior quality and appearance of the bulk of the tobacco cured by the leaf-process as indicated by the sale, was mainly due to the fact that the leaves were harvested as they became mature. By the stalk process many of the lower leaves were over-ripe, while the tips were still green. In addition, it is believed that the leaves received less damage from handling by the leaf-curing process than when handled on the stalk.

4. The difference in chemical composition of like grades resulting from the two methods of curing is chiefly due to the manner and time of harvesting. This difference is most noticeable in case of the fillers, where the increased growth, caused by priming the lower leaves in the leaf-curing process, has made a large increase in the percentage of albuminoids and nicotine. Some of the differences are also due to the variation in composition of leaves from different parts of the stalk selected to make up these grades.

5. The chemical composition of tobacco cured by similar methods is not materially affected by separating the leaf from the stalk before curing, provided the condition of the tobacco is the same when put in the barn.

6. The time required for curing leaves from different parts of the plant varies according to their ripeness. Some of these leaves require an entirely different range of temperature from others to produce the required color, etc. For these reasons the leaf-curing process is more desirable, as the barn is filled each time with tobacco requiring like treatment to produce the best results in color, quality and general appearance.

7. The priming process as followed in the leaf-cure method has a marked effect on the growth and chemical composition of the leaves taken from the upper part of the plant. The removal of the lower leaves causes the top of the plant to grow with increased vigor, thus producing heavier and coarser leaves, with a considerable increase

in the percentage of organic nitrogenous matter and nicotine. While the quality is somewhat injured by this transformation, it appears that the gain in weight more than compensates for the loss in quality.

8. The slightly larger percentage of resins and fatty substances resulting from the stalk process, as compared with the leaf process, is not worthy of especial notice, on account of the smallness, and probably results from the deficiency of the other constituents.

9. The excess of sand found in the best grade wrappers from the leaf-curing process indicates that a portion of the lower leaves were classed as wrappers which were not available as such by the stalk process.

10. The presence of a large percentage of carbohydrates, especially starch and glucose, is characteristic of the yellow tobacco grown on the light, sandy soil of Granville county. This soil, although containing a remarkably small percentage of available mineral matter, seems to be peculiarly adapted to the development of these organic compounds. The character of soil may also cause the low percentage of ash, as compared with other varieties.

11. The higher ash percentage by the leaf-curing process is due to the time and manner of harvesting rather than the method of curing. The analyses of the ash of the best grade wrappers from both processes show some variations in chemical composition, which are evidently due to the conditions of growth, etc., affecting the tobacco before the curing was commenced.

12. The complete organic and inorganic analyses of stalk, stem, and leaf, as tabulated in preceding tables, are of interest, as showing the relative percentage of the various constituents found in the different parts of the plant.

13. The carefully regulated drying by artificial heat, as practiced in the Snow barn and the old-style log-barn, reduces the fermentative changes, which take place in the process of curing, to a minimum. Of all the organic compounds, glucose is especially liable to change in the process of curing, but in this case it is believed that practically the whole amount which was present in the green leaf remains unchanged in the dried product.

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